Field Data Collection with Global Positioning Systems

Standard Operating Procedures and Guidelines

02/10/04

GIS Division, NISC-OCIO-WASO
National Park Service

Summary

This document addresses GPS instrument settings, field operation, data processing, data collection and standardizes the development and management of positional data. GPS is often referred to as the back door to GIS, and is a widespread method of creating spatial data for unique park features that are not produced by other organizations, such as USGS.

Organizational Justification

The NPS annually spends approximately $24M on spatial data. This figure only includes large GPS projects and initiatives that are reported for the NPS section of the annual NASA report. It is hard to estimate the staff time and equipment costs incurred at parks for mapping trails, signs, etc on a smaller scale. There are probably thousands of GPS units in the NPS being used on a regular basis. The use of standard operating proceedures and data standards help to ensure that the investment of NPS staff time and equipment purchases result in useable products that can be shared with others in a variety of formats and systems.

The standardization of NPS spatial data, centralized data management and serving saves the NPS $3M per year. The NPS supports and organizes national geographic data development for public consumption through ParkNet's Interactive Map Center and the GIS Data Clearinghouse accessed by millions of people every week via the Internet. The GIS Data Clearinghouse is an official node of the National Spatial Data Infrastructure, required by Executive Order 12906. This national effort saves each region and program office from having to support a similar infrastructure and developing regional expertise to carry out this federally mandated service. These activities also reduce demand on individual parks, regions, and program GIS staff, by making these data available to the public and NPS sites through conventional web resources.

Definition of the Global Positioning System

GPS (Global Positioning System) is currently a constellation of 25 Department of Defense satellites that orbit the earth approximately every 12 hours, emitting signals to Earth at precisely the same time. The position and time information transmitted by these satellites is used by a GPS receiver to trilaterate a location coordinate on the earth using three or more satellites.

The satellites broadcast on two carrier frequencies in the L-band of the electromagnetic spectrum. One is the "L1" or 1575.42MHz and the other is "L2" or 1227.6MHz. On these carrier frequencies are broadcast codes, much like a radio or television station broadcast information on their channels (frequencies). The satellites broadcast two codes, a military-only encrypted Precise Position Service (PPS) code and a civil-access or Standard Position Service (SPS) code.

GPS Receivers

All commercially available consumer GPS receivers are SPS receivers. There are two basic types of SPS receivers, those that use the broadcasted code to do positioning (code-phase) and those that do carrier phase measurements (carrier-phase). PPS or P(Y)-Code (Rockwell PLGR and Trimble Centurion) receivers utilize the P(Y)-code broadcast on the L2 carrier frequency for positioning. This type of receiver is only available to the military and some government agencies.

Positional Data

The National Map Accuracy Standard (NMAS) published by the USGS is the NPS *minimum* standard for map data accuracy. Typically a GPS will provide much better accuracy then NMAS if it is used carefully and with full attention to the parameters that the user can set or track. To achieve a reasonable and reliable level of accuracy with a GPS, please use the parameter settings described below. Please note that different GPS units use different names for these parameters or define them slightly differently. The discussion below tries to accommodate for these differences. If you have any questions please contact Tim Smith at Tim_Smith@nps.gov or your regional GIS coordinator.

GPS Positional Accuracy

Positional accuracy for autonomous, code-phase, resource grade or C/A-code receivers range from 100 meters to less than 1 meter. Accuracy for carrier-phase units (commonly referred to as geodetic receivers) can be measured in millimeters.
Accuracy is dependent on a number of factors. Several factors that can significantly impact data accuracy can be monitored in the field: the number of satellite vehicles, Positional Dilution of Precision (PDOP), signal-to-noise (SNR) and Estimated Horizontal Error (EHE). One should always acquire at least 4 satellites. This gives you a 3D position. More satellites are better than fewer. PDOP relates to satellite geometry at a given time and location. Keep the PDOP as low as possible (ideally, maximum PDOP=4) when collecting mapping data. Some receiver's have the ability to limit collection of GPS data if certain GPS quality measures such as PDOP, SNR and number of satellites are out of range. These are referred to as masking. Most receivers (but not all) give you a field estimate of horizontal error (EHE or EPE). With the Rockwell PLGR and Garmin line of receivers, the EHE (or EPE) has been shown to be a very good indicator of overall positional accuracy (most of the time your accuracy is going to be better than the EHE). In the field, EHE is not presently available on the Trimble line of receivers.

Positional accuracy for both C/A-Code and carrier-phase types of receivers can strongly depend on a process called differential correction. In order to achieve greater accuracy, the differential correction procedure is used to limit Selective Availability (controlled by the Department of Defense (DoD) and Ionospheric/Tropospheric degradation of the satellite signals. Although DoD has now set Selective Availability degradation to zero, Ionospheric / Tropospheric degradation can add from 1 - 7 meters of error to your position. Therefore, differential corrections are required to improve accuracy, maintain positional integrity (confidence), and make a survey tie to a ground-based geodetic survey network.

Differential corrections should be used whenever possible. This removes the greatest source of errors remaining in the GPS error budget. Real-time differential corrections are available through the NDGPS/Coast Guard Beacon System, the WAAS (FAA) satellite based differential system, OmniStar, or a variety of paid private differential services. Post-process differential GPS can be obtained from the NGS base stations available from the web or local community base stations.

Real-time differential corrections should be used whenever possible. This saves both time and money.

Receiver-Specific Recommended Settings:

Garmin and PLGR units:

1. *EHE*: less then or equal to 12 meters. This will keep you just within the NMAS for a 1:24,000 map, which is the maximum acceptable.
2. *Minimum of 4 satellites (3D)* for every position.
3. *Position Type*: If possible and practical, real-time differentially corrected positions should be collected.

** Note: Because neither of these units operating in autonomous mode can mask for GPS quality, it is up to the user to monitor constantly the Satellite page for quality.

Trimble units Pathfinder Systems (PRO XR's, XRS's and GeoExplorers):

1. *PDOP*: less then or equal to 6 (we recommend starting with a PDOP maximum of 4 and shifting to 5 if data collection is not successful at 4; this will keep you around the NMAS for a 1:5,000 map).
2. *Minimum of 4 satellites (3D)* for every position.
3. *SNR*: less then or equal to 5.
4. *Elevation Mask*: 15.
5. *Antenna height*: be sure to check for correct antenna height setting. This setting should be the typical height at which the antenna will be carried. If the antenna is attached to a pole, it must be located above the user's head and the antenna height setting should be the height of the top of the pole. Wherever possible, the antenna should be clear of any obstructions.
6. *Position Type*: Must be post-processed or real-time differentially corrected.

All GPS units:

1. Check the graphics data collection screen regularly to see if you are getting multi-path or other apparent distortions to the data. Garmin and PLGR's require the user to monitor the screen and stop data collection during poor PDOP or SNR windows. Trimble receiver's set to the appropriate mask will stop collecting automatically.
2. Be aware of the possibility of multi-path interference and use offsets or other methods to keep the antenna away from building overhangs, tall fences or walls, and heavy canopy wherever possible.
3. ALWAYS do differential corrections, either real-time or post processed.
4. Feature settings:

Point

- *Trimble* - minimum of 30 positions, collected at 1 second interval and averaged.
- *All Others* - 90 to 180 positions, collected at 1-2 second interval and averaged.

Line/Polygon

- use a 2-5 second interval for walking and for road driving, depending on the road type and speed of the vehicle, force (i.e. wait for) a position at each corner, and use a minimum of 3 positions to define any curve/change in direction.

** Note: If maximum accuracy is required, it is important to sync the collection rate with the base station logging rate. Stations log anywhere from 1 to 30 second data. It is recommended that logging rates to be in multiples of 1 or 5 for best differential corrections. Setting logging rates other than 1 and 5 may reduce the number of positions that are in sync with base data and reduce accuracy.

5. Try to map all features in a single area in a single day or on consecutive days.

Attribute Data

Data dictionaries (e.g. Trimble) or data collection forms (e.g. ArcPAD) are designed to simply, efficiently, and without redundancy, describe features (landscape, biological, cultural, or historical). A data dictionary or form organizes data into types or 'themes' and reduces user error when entering values. It is an efficient use of time and energy to employ this type of data collection. Set up a menu and picklists in a database and load them into the GPS unit or data collection device prior to going out into the field. Create and use a data dictionary or data collection form whenever possible to collected attribute data.

Coordinate Metadata

Record the following at a minimum:

1. EHE/EPE or maximum PDOP (using 4 satellites)
2. Coordinate datum
3. Coordinate projection
4. Projection Zone, if using UTMs or State Plane

The following parameters should be used in selection of datum and projection:

Projection and Coordinate System

All digital geospatial data should reference the coordinate system appropriate for it's use and it should be documented in the metadata. All spatial data collected or submitted for national, regional, or network NPS programs shall be geo-referenced and provided in a standard projection. Digital geospatial data should be referenced to two coordinate systems--the current standard system used by the individual park (generally UTM, NAD83) and a regional-scale system (Geographic, NAD83). The steps used to get the data into the proper projection must be documented in the metadata. The project manager must specify, approve and document any deviation from these projection standards.

NPS-wide and Regional Data Standard

The standard projection for most NPS regions and national programs is geographic with the following parameters as per Executive Order 12906 (http://www.fgdc.gov/publications/documents/geninfo/execord.html) and the Federal Geographic Data Committee (FGDC) standards:

Datum	North American Datum 1983

Spheroid GRS 1980
Units Decimal Degrees

Park Unit Data Standard
The standard projection for most NPS regions and national programs is Universal Transverse Mercator (UTM) with the following parameters:

Projection Universal Transverse Mercator
Datum North American Datum 1983
Spheroid GRS 1980
False Easting 500,000
False Northing 0
Units Meters

Unit Standards for Exceptions
In addition to the systems noted above, several NPS units require additional specific standards for data delivery (e.g., Cabrillo and Craters of the Moon National Monuments). Parks in Hawaii and other Pacific islands will be in the datum and projection specified by each park. Because of their geographic location, the NPS Alaska Region also requires a specific datum and projection as noted below. However, data sets for use regionally and systemwide should be provided in latitude / longitude (decimal degrees) and NAD-83.

Alaska Region
The standard projection for Alaska Region parks uses the following parameters:

Projection Alaska Albers Equal Area
Datum North American Datum 1927
Spheroid Clark 1866
False Easting 0
False Northing 0
Central Meridian -154 00 00
1st Standard Parallel 55 00 00
2nd Standard Parallel 65 00 00
Units Meters

Horizontal / Vertical Accuracy and Precision
All spatial data collected shall be analyzed for their spatial accuracy and shall meet or exceed the National Map Accuracy Standards for the particular scale intended (for more information see http://mapping.usgs.gov/standards/). Longitude and Latitude coordinates for geographic data should be recorded to a minimum 5 significant digits to the right of the decimal point and stored in double precision attribute or database fields. Any calculations done with location data should be done at double precision with the results rounded or truncated to the appropriate propagated error limits. All calculations and processing completed on the spatial data shall be reported in the metadata.

Additional Data Collection Notes

- Positional coordinate data should not be recorded in NAD-27 in the field. Datum conversions should be done as an office, post-process activity using software that utilizes a full NADCON datum conversion in order to assure accuracy and precision. GPS receivers do not do a full NADCON conversion and should, therefore, not be relied upon to accurately convert back and forth from NAD-27 to NAD-83. Errors can be 4 meters or more.

- When estimating distances, Latitude / Longitude decimal degrees can be used the same as Universal Transverse Mercator coordinates (UTMs). The digit in the fifth decimal place of decimal degrees can be used as approximately a meter.

- Real-time differential techniques should be employed whenever possible for efficiency and time savings.

- The distance between the base station and the remote GPS receiver should be kept to a minimum, preferably less than 150 mi.